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Research Note

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FORCES IN BALLOON LOGGING

by

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This note is furnished to provide a better understanding of the mechanics of yarding with a balloon. The sources of the individual forces involved are discussed, and a possible combination of these forces to produce lift and movement of the log is illustrated. Figure 1 shows a typical configuration for balloon logging.

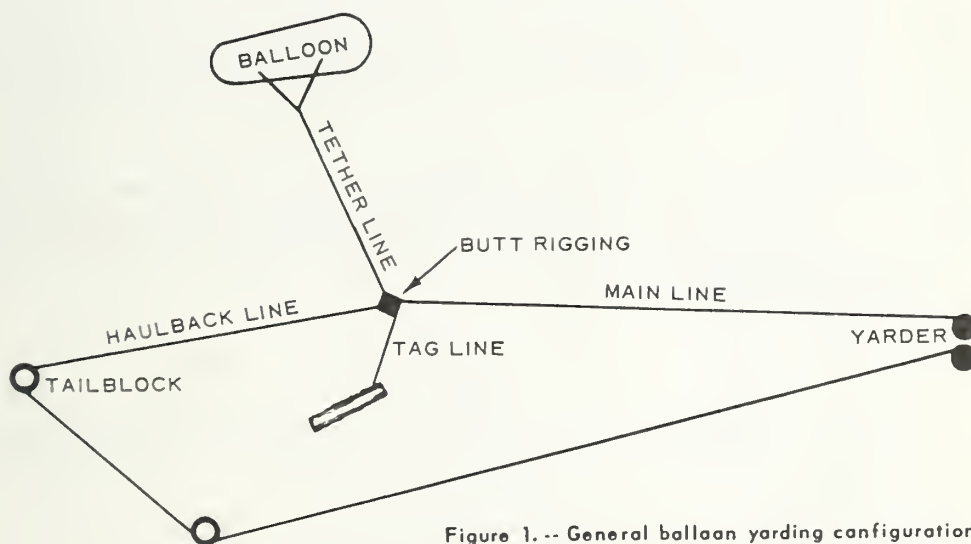


Figure 1.-- General ballaon yarding configuration.

BALLOON-INDUCED FORCES

The following balloon forces combine vectorially to produce a tension in the tether line:

1. Net static lift force (F_s): Vertical force due to buoyancy of gas less weight of bag and rigging.
2. Inertia force (F_i): Force produced by accelerating the balloon. Mathematically, this is

$$F_i = m a$$

where: m = mass of gas

+ mass of balloon

+ mass of air accelerated with the
balloon

a = balloon acceleration

The mass of air accelerated with the balloon is determined by using inertia coefficients which depend on the shape of the balloon. The air mass is obtained by multiplying the mass of air displaced by the inertia coefficient. The inertia coefficients are determined along the principal axes of a body. For accelerations in other directions, the acceleration is first resolved into components along the principal axes, then the force components are calculated in the principal directions, and finally, the force is obtained by vector addition. To determine this force, the magnitude and direction of the balloon acceleration must be known as well as the balloon inertia coefficients and the angle between the balloon axis and the acceleration vector.

3. Aerodynamic lift force (F_l): A force component perpendicular to the direction of air motion past the balloon which is produced by the air motion. Mathematically, this component is

$$F_l = C_L \frac{\rho}{2} v^2 V_H^{2/3}$$

where: C_L is the lift coefficient and varies with the angle of attack and the balloon configuration

ρ is the mass density of air

v is the air velocity relative to the
balloon

V_H is the balloon volume

4. Aerodynamic drag force (F_d): A force component in the direction of air motion past the balloon which is produced by the air motion. Mathematically, this component is

$$F_d = C_D \frac{\rho}{2} v^2 V_H^{2/3}$$

where: C_D is the drag coefficient and also varies with the angle of attack and balloon configuration

The relative air velocity in the lift and drag force equations above is the vector sum of the ambient wind and motion of the balloon relative to the ground. The direction of this relative velocity is not necessarily horizontal. These forces can be determined if the magnitude and direction of the relative air velocity, the balloon attitude relative to the velocity, and the coefficients for the balloon attitude are known.

All of these forces can combine to produce an upward force as in the example illustrated in figure 2.

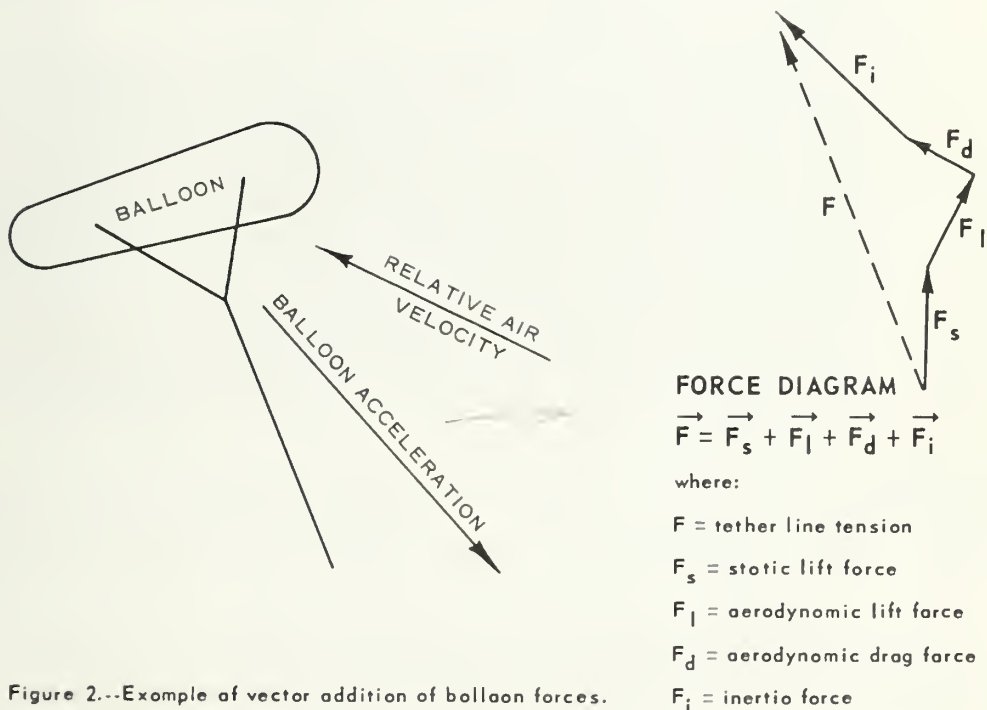


Figure 2.--Exemple of vector addition of bolloon forces.

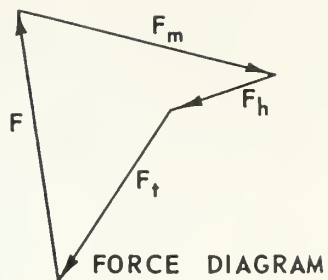
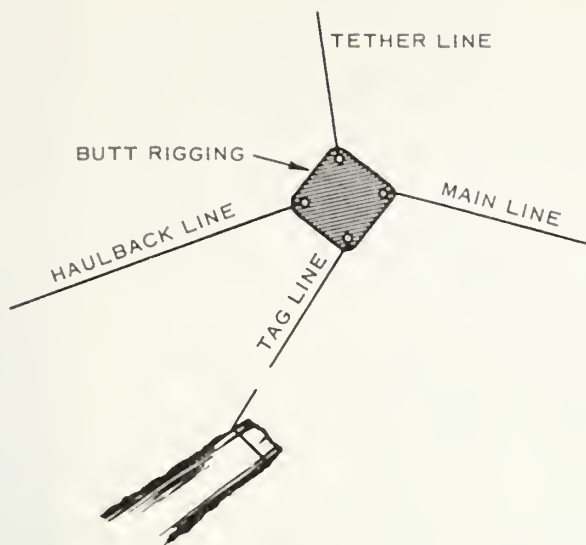
FORCES AT BUTT RIGGING

The butt rigging is the junction point of the balloon tether line, the main line, the haulback line, and the tag line to which the logs are attached. The source of the tether line tension is fully described in the discussion above. At the butt rigging, this tension is reduced from that at the balloon due to the weight of the tether line. A description of the forces in the remaining lines while yarding the logs into the landing is given below:

1. Main line tension: This force is produced by the yarder through the main line drum and by the weight of the cable. The force at the butt rigging may be less than at the yarder due to: (1) friction if the line contacts the ground, (2) friction in the blocks, (3) inertia of the line during periods of acceleration, and (4) difference in elevation between yarder and butt rigging.
2. Haulback line tension: The force in this line is due to (1) friction between the line and the ground; (2) friction in the blocks; (3) haulback drum induced forces caused by friction, braking, or interlocking with the main drum; and (4) the weight of the cable. The cable weight will alter the tension at the butt rigging by the product of the unit cable weight and the difference in elevation between the butt rigging and the yarder. During periods of acceleration, inertia of the haulback line will cause an additional tension in this line.
3. Tag line tension: The magnitude of this force at the log is less than at the butt rigging due to the weight of the tag line. During the lift-off phase of yarding, the magnitude and direction of the force produced by the tag line must be sufficient to produce a force component on the log to overcome the friction force between the log and the ground. For log acceleration, the tag line tension must also overcome the inertia of the log. After lift-off, the force in this line must equal the weight of the log if the log is to remain free of the ground and must exceed half the weight of the log if the log is to be yarded with one end off the ground.

Tag line tension is of primary interest since this is the force that lifts the logs. Figure 3 shows an example of the tension in the other three lines adding vectorially to produce a tag line tension.

This general force description does not consider phenomena which will cause transient variations in the forces such as oscillation of the balloon-log system or sudden impact of the log with a ground obstruction.



FORCE DIAGRAM

$$\vec{F}_t + \vec{F} + \vec{F}_m + \vec{F}_h = 0$$

where:

F_t = tog line tension

F = tether line tension

F_m = moin line tension

F_h = houlback line tension

Figure 3.--Exomple of vector oddition of line tensions.

